Role of structural requirements in web-site selection in *Cyrtophora cicatrosa* Stoliczka (Araneae: Araneidae)

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Cyrtophora cicatrosa weaves a three-dimensional dome web and is commonly found in thorny bushes and cacti. The factors that could be responsible for this selection were studied, both by field observations and laboratory experiments. Structural requirements in terms of space availability were found to be an important factor in the selection of the web site, though other factors could be significant. The relationship between *C. cicatrosa* and its immediate environment is discussed.

CYRTOPHORA cicatrosa is a sedentary, solitary spider which builds a complicated three-dimensional dome web, expending a large amount of energy and time (Figure 1). Spiders with such complex webs tend to move less[1] and hence the site where they construct their webs is very important with respect to food availability, protection against the predators, etc. The present study focused on the abiotic parameters that could influence web-site selection. While a lot of studies[2,3] have focused on the importance of prey availability towards web-site selection, we tested the influence of abiotic factors such as substratum characteristics, space availability and effect of plant architecture on the site selection. This was done by integrating field measurements with lab experimentations. The actual lengths of the strands used to affix the dome to the substratum were measured and a relation between the dome volume and the anchor length was investigated. By varying the available space by artificial means, we could arrive at a threshold value needed for the construction of a typical web. *C. cicatrosa* is typically found to weave webs in a few plant species (e.g. *Borassus flabellifer* and *Euphorbia quadrangularis*), which are similar only in that they provide enough space to construct a normal-sized web. This study aims to quantify the threshold level of complexity of the plant architecture, viz. what kind of plant would be suitable to the spider.

The species, commonly called 'dome spider', shows sexual dimorphism, with the female being several times larger than the male. The young reach adulthood in 75 days. Adults, during their span of 150 days, lay 5–20 pear-shaped egg sacs in a beaded chain that hangs at the central part of the upper barrier web[4]. The web is a modified orb web, lacking a sticky spiral and in its place there is a very fine-meshed non-sticky spiral, equivalent to the temporary spiral of other orb weavers (Lubin, pers. commun.). The spiral is held in position by numerous irregular anchor strands that are attached to the surrounding substratum. The dome can be considered as the centre of the web. The spider typically hangs upside down at the peak of the dome. This web is a non-sticky knock-down web[5], i.e. the presence of prey is signalled by the vibration of the strands.

The study was conducted in the southern part of Pondicherry University Campus, Pondicherry in South India. Scrub savannah dominates the terrain and is intermixed with plantations of *Acacia* sp., *Anacardium occidenatale* and *Eucalyptus* sp. A general survey of the site revealed that despite the presence of other plants, *C. cicatrosa* were found mostly on 4–5 species such as *B. flabellifer*, *E. quadrangularis*, *Phoenix pusilla*, *Pandanus* sp. and an unidentified Rubiaceae member. The laboratory work was conducted in the Department of Ecology at the same university.

Space availability can be defined in terms of the three-dimensional area required by the spider to construct a complete web. Since this area varies among webs, it was quantified by measuring the lengths of the principal anchor strands (Figure 2) radiating from the centre of the web. Webs ($n = 31$) of adult females were considered for measurement. The study was done between the months May and June (summer) of 1997. Measurements were made by plotting the extreme points of the anchor strands directly onto an *xyz* axis. The extreme points refer to the place where the anchor strands attach to the substratum. The formula used to calculate anchor length was:

$$AL = \sqrt{\{(x1-x2) + (y1-y2) + (z1-z2)\}},$$

where AL is the anchor length and *x*1, *y*1, *z*1 and *x*2, *y*2, *z*2 are the coordinates of the two points (between the centre of the web and the anchor point), respectively.
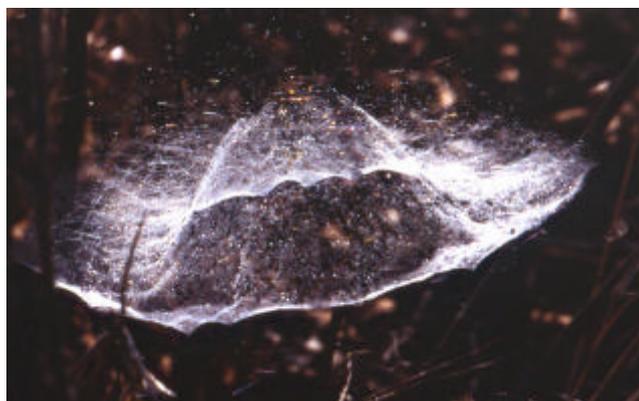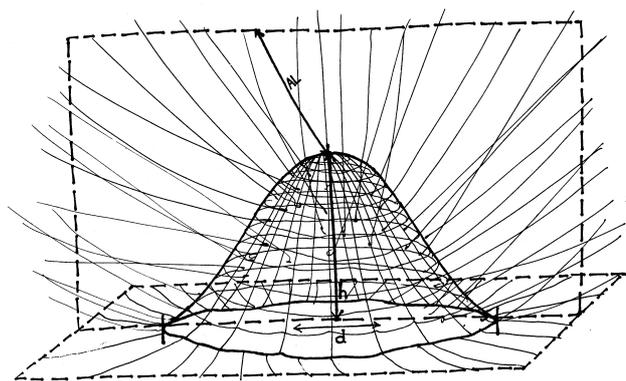

Figure 1. A typical dome web of *Cyrtophora cicatrosa*.

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Figure 2. Stylized structure of *C. cicatrosa* web showing measurements taken.

Treating the dome peak as the origin, volume of the dome ($V = 1/3(pr^2h)$) approximated to a cone was found by measuring the height (h) and the base length (r = radius) in 31 spider webs. The radius was considered as half the diameter (d).

Laboratory studies were carried out by permitting adult female spiders to spin webs in aluminum cages with steel mesh walls. The size of these cages ranged from 10 cm × 10 cm × 10 cm to 20 cm × 20 cm × 20 cm. Mosquitoes were fed through an opening at the top of the cage. These studies included: (1) Allowing spiders to spin webs in cages of different sizes to determine the effect of increased space availability on the web structure. (2) Introduction of obstructions (sticks) in control cages to simulate the effect of complex plant architecture. (3) Observing the effect of light during web-building, by varying the intensity of light incident on the web.

Dispersion studies were carried out in the field in three quadrats. The nearest neighbour method of estimating dispersion[6,7] was used, by considering the dome peak as the point of reference in three 12 m × 12 m quadrats and using the following formulae ((1)–(4)):

$$r_a = \Sigma r_i/n, \tag{1}$$

where r_a is the mean distance to the nearest neighbour, n is the number of individuals in the study area and r_i is the measured distance to the nearest neighbour for an individual i.

$$r_e = 1/2\sqrt{r}, \tag{2}$$

where r_e is the expected distance to the nearest neighbour and r is the density (number in the study area/size of the study area).

Deviation of the observed pattern from the expected random pattern is

$$R = r_a/r_e, \tag{3}$$

where R is the index of aggregation.

Test of significance for deviation from randomness is

$$Z = R_a - R_e/s_r, \tag{4}$$

where Z is the standard normal deviate and s_r is the standard error of the expected distance to the nearest neighbour = ($0.26136/\sqrt{nr}$), with n being the number of individuals in the study area and r the density of individuals in the study area.

The irregular strands taper off into anchor strands. The lengths of the anchor strands were correlated against the volume of the dome to test the hypothesis that a larger dome would require longer strands. There was no correlation ($r = 0.13$). The dome parameter ratio (height : diameter) was estimated to have a mean of 3.6 (std. dev. = 1). The low standard deviation implies that the overall proportion of the web remains constant, despite the changes in the actual measurements of the web parameters.

In the experimental set-up, there was a direct correlation between the volume of the dome and the volume of the cage ($r = 0.86$, $P < 0.05$). This implies that the larger the space available, the larger the size of the web till a certain threshold size is reached. When a spider was set in a large cage (i.e. greater than 20 cm × 20 cm × 20 cm), the spider tended to weave its web in a corner, rather than in the centre of the available space. When the cage size was too small (i.e. lesser than 10 cm × 10 cm × 10 cm), the spider did not weave the typical dome web, but spun some irregular strands. When obstacles (twigs) were introduced, the dome tended to be located away from the sticks. The twigs were never incorporated into the dome. *C. cicatrosa* builds its web at night and the dome is built last. Spiders, when exposed to continuous source of light did not build a web.

The deviation of the population from random distribution was checked for and was found to be significantly different from the random pattern ($z > 1.96$), according to the Clark and Evans Test[6]. The index of aggregation was calculated for the quadrats and the values obtained were 0.04, 0.01 and 0.02 for $Q1$, $Q2$ and $Q3$, respectively. This indicates clumping.

The study on space available reveals that the dome exists relatively independent of the anchor strands. Thus the irregular strands adapt to the irregularity in the plant structure. The dome size is relatively constant for adult spiders and hence it can be considered as the most important part of the web. However, functionally, the purpose of the dome is under debate. Some authors feel that it serves as a defence against predators[8]. It could also be a refuge from rain and debris. However, it has been observed that when disturbed, the spider drops to the ground trailing draglines. This is more of an anti-predator response. The laboratory studies indicate that the volume of space available determines the volume of the dome. This was illustrated by the fact that when the cage was too small (10 cm × 10 cm × 10 cm), the dome was not built. This was also noticed in a separate study[4]. All host plants in the study site provided enough space for an adult spider to build its web.

The importance of the architecture of the host plant was revealed in an experiment with regard to obstacles. Obstructions in the form of sticks were introduced in a cage of dimensions 21 cm × 21 cm × 18 cm. The dome, which was usually built at the centre of the area in a control cage, was now shifted to one side and was smaller in size.

Prey capture efficiency in *C. cicatrosa* is lesser than a sticky trap of comparable size[5]. Prey availability is known to influence web-site selection in several spiders[2,3], but is unlikely to do so in this case for the following reasons: (1) Inefficient web in terms of prey capture[8], compared to an equivalent-sized sticky web. (2) The spider is unlikely to abandon its web easily, since a large amount of energy has been spent during web construction[1].

Prey considerations are likely to be secondary to architecture considerations, as the web structure is affected by space limitations, i.e. the web has to be built first before the quality of the site (in terms of prey availability) can be determined.

Dispersion measurements indicate that there is a high degree of clumping. Even though *C. cicatrosa* is solitary, it is found in aggregations. Hanschel and Lubin[9] studied web-site selection in a desert spider and concluded that *Seothyra hanscheli* does not actively choose sites, but has a restricted dispersal. Site tenacity may be a result of the spider's inability to predict site quality coupled with high costs of relocation. They inferred that spiderlings tend to remain near the mother's site, that had a previous record of success. This explanation could be the reason for a high aggregation in *C. cicatrosa* as well. Dispersal could be affected by the wind, but since the webs are found in sheltered areas, this is minimized. A possible implication of aggregation is that *C. cicatrosa* is on the way towards the evolution of sociality, as all the other members of this genus have done.

Structural requirement is the most important factor for the web-site selection in *C. cicatrosa*. A suitable way to classify plants according to their structural complexity is through the use of fractal dimensions, as laid out by Lawton[10]. A further analysis of the web structure could lead to better understanding of the spider's needs and its interaction with the environment.

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Restriction of mitochondrial oxidative metabolism leads to suppression of photosynthetic carbon assimilation but not of photochemical electron transport in pea mesophyll protoplasts

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The present study examines and establishes the primary effect of mitochondrial inhibitors, oligomycin, antimycin A and salicylhydroxamic acid (SHAM), on the photosynthetic carbon assimilation and photochemical electron transport activities, monitored in intact mesophyll protoplasts. These inhibitors caused a marked restriction of malate (+ glutamate)-dependent O_2 uptake in mitochondria (53–73%) isolated from pea leaves. When mesophyll protoplasts were illuminated in the presence of mitochondrial inhibitors, there was a significant decrease (> 45%) in HCO_3^--dependent O_2 evolution, while the decrease in O_2 evolution was marginal (< 10%) in the presence of benzoquinone (BQ) (photosystem PSII-mediated) and NO_2^--(dependent on PSII + PSI) as electron acceptors. 3-(3.4-dichlorophenyl)-1,1-dimethylurea (DCMU), a typical photosynthetic inhibitor decreased drastically all the three reactions: HCO_3^- or BQ or NO_2^--dependent O_2 evolution in mesophyll protoplasts. Our results indicate that mitochondrial oxidative metabolism (through both cytochrome and alternative pathways) is essential for maintenance of photosynthetic carbon assimilation, but not for PSI or PSII-dependent photochemical electron transport activities in mesophyll protoplasts of pea.

APART from meeting energy requirements in dark, mitochondrial respiration plays an essential role in maintenance of photosynthesis. Restriction of mitochondrial metabolism decreased the rates of photosynthetic carbon assimilation while increasing the lag[1–6]. Mitochondrial oxidative metabolism through both oxidative

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